10/511874
DT01 Rec'd PCT/PTC 18 OCT 2004

COMBINATION CHAMBER WITH FLAMELESS OXIDATION

[0001] The invention concerns a combustion chamber for a gas turbine and a gas turbine equipped with such a combustion chamber.

[0002] Gas turbines are used to convert heat energy to mechanical energy, which is delivered to a shaft (power plant, ship power plant, helicopter) or as thrust (aircraft). All gas turbines have combustion chambers in which a fuel is burned with excess air. A stable flame is then formed in the combustion chamber. The gas flow, which has a very high velocity at the compressor outlet, is generally initially slowed for stabilization. Appropriate means are provided to form stable flames. For example, small eddies are generated in the combustion chamber for flame stabilization. Combustion occurs with excess air so as not to cause thermal overload of the combustion chamber and turbine.

[0003] Flameless oxidation of a fuel in a corresponding reaction space is known from EP 0463218 B1. Flameless oxidation is achieved at high combustion temperatures when the fuel is introduced to a hot exhaust- and oxygen-containing gas stream.

[0004] Combustion chambers of gas turbines must satisfy several requirements. Some of them are the least possible pressure loss, as complete as possible combustion, falling (just) short of the maximum exhaust temperatures (to spare the turbine), and limited generation of NO_x.

[0005] The task of devising a combustion chamber that has low NO_x generation and is suitable for use in gas turbines is derived from this.

[0006] This task is solved with the combustion chamber according to Claim 1:

[0007] The combustion chamber according to the invention is set up for flameless oxidation. This is achieved by aligning the inlet and outlet so that a large-volume recirculation flow is formed in its internal space, with which larger amounts of hot exhaust gases are mixed with the supplied fresh air. The ratios are preferably such that at least twice as much exhaust stream is mixed with the fresh air stream. Consequently, a situation can be achieved in which the mixture of fresh air and exhaust has a mixing temperature that lies above the ignition temperature of the fuel. The flameless oxidation that develops does not rely on formation of a stable flame. Relatively high gas velocities can therefore be used, in which oxidation of the fuel extends over a larger zone between the inlet and outlet.

[0008] The large-volume recirculation flow can also be configured to be relatively low loss, so that the combustion chamber has low flow resistance and therefore causes only limited pressure losses. Pressure losses that lie in the range of less than 3% of the combustion chamber pressure are attainable. The fresh air is compressed and preferably fed to the combustion chamber as an air jet free of rotation. Ordered flow is produced.

[0009] The new combustion chamber permits high power densities (for example 100 MW/m^3). Flame collapse and blowback are in principle impossible. NO_x concentrations of less than 10 ppm are achieved.

[0010] To form flameless oxidation with simultaneous achievement of a low flow resistance of the combustion chamber and a compact design, the fuel is introduced to the combustion chamber in the same direction as the fresh air. Because of this, local eddies, which otherwise might contribute to an increase in pressure loss, are largely reduced.

[0011] The combustion chamber is preferably laid out with an internal recirculation of 2 to 5. This means that exhaust gas two to five times the mass flow of fresh air is mixed in with it.

[0012] The air and fuel are then preferably introduced coaxially in adjacent jets or in jets otherwise arranged next to each other and essentially parallel in the combustion chamber. Feed to the combustion chamber preferably occurs from the end wall at the region adjacent to the outer wall of the combustion chamber, i.e., in a zone of the end wall lying radially outward. Because of this, fresh air and fuel are initially introduced into the combustion chamber in an essentially wall-parallel flow. The outlet of the combustion chamber is preferably oriented in the same direction or the opposite direction, its outer boundary being closer to the center axis of the combustion chamber than air nozzles for inlet into the combustion chamber. A recirculation stream of larger volume can be achieved with this expedient. It is guided along the wall from the inlet to the outlet of the combustion chamber, and then flows back from the outlet to the inlet, preferably on the center axis of the combustion chamber.

[0013] The inlet of the combustion chamber is preferably formed by several air inlet nozzles that guide the fresh air into the internal space as fresh air jets. The air nozzles are also preferably formed so that the emerging air jet exerts an injector effect for return flow of exhaust gases. This can be achieved or supported by a conical section protruding above the end wall of the combustion chamber.

[0014] The combustion chamber can be part of individual combustion chambers arranged in annular fashion in a set, which are also referred to as tubular combustion chambers. As an alternative, the combustion chamber can be laid out as an annular combustion chamber. In stationary installations alternative combustion chamber shapes are also possible.

[0015] The combustion chamber is preferably designed so that it has only a single circulation center (turbulence center). In the tubular combustion chamber this turbulence center is a line or surface arranged coaxial to the combustion chamber longitudinal axis. The circulation stream is a toroidal stream that encompasses the entire internal space of the combustion chamber. In the annular combustion chamber, in which the air nozzles belonging to the inlet are arranged, for example, on an outer rim in the end wall, the

turbulence center is also formed by a circular line aligned coaxial to the longitudinal axis of the combustion chamber. This is preferably roughly parallel to the line along which the air nozzles are arranged.

[0016] The combustion chamber is preferably provided with a preheating device with which it can be brought at the beginning of operation to a temperature suitable for flameless oxidation. The preheating device is formed, for example, by temporarily operated burners that can form a flame by means of electric heating or other heat sources.

[0017] The combustion chamber can be coated on its inside wall with a catalytically active material. In addition, a guide element with a catalytic surface can be arranged in the combustion chamber. A catalyst can also be arranged at the outlet of the combustion chamber.

[0018] Other advantageous details of variants of the invention are apparent from the drawing, description or dependent claims.

[0019] Embodiments of the invention are explained in the drawing. In the drawing:

[0020] Figure 1 shows a gas turbine in a schematic view,

[0021] Figure 2 shows the combustion chambers of the gas turbine according to Figure 1 in a front view,

[0022] Figure 3 shows an individual combustion chamber in a schematic, longitudinal view,

[0023] Figure 4 shows the combustion chamber according to Figure 3 in a front view,

[0024] Figure 5 shows a modified variant of the combustion chamber in a longitudinal view,

[0025] Figure 6 shows another modified variant of the combustion chamber in a longitudinal view,

[0026] Figure 7 shows a combustion chamber designed as an annular combustion chamber in a front view,

[0027] Figure 8 shows a combustion chamber according to Figure 7 in a longitudinal section,

[0028] Figure 9 shows a combustion chamber with reverse flow in a longitudinal view and

[0029] Figure 10 shows the combustion chamber according to Figure 9 in a front view.

[0030] A gas turbine 1 having a compressor 2, a turbine 3, which is connected to the compressor 2 via a shaft 4, and at least one combustion chamber 5, is shown in Figure 1. Each combustion chamber has an inlet 6, which is fed compressed air from compressor 2, and an outlet 7, which supplies the gas stream generated in combustion chamber 5 to turbine 3.

[0031] The combustion chambers 5, as shown in Figure 2, can be roughly can-type burners which together form a combustion chamber set. A single such combustion chamber

5 is shown in Figure 3. The combustion chamber has an internal space 9 enclosed by a wall 8, which is essentially cylindrical. On the inlet side an end wall 11, which can be designed flat, is part of the wall 8. On the opposite side an end wall 12 is formed in which an opening 14 with radius B that defines the outlet 7 is arranged. A series of air nozzles 15 which, as shown in Figure 4, are arranged in a circle, serves as inlet 6. The air nozzles 15 are arranged in the vicinity of wall 8 at a radius A, greater than the radius B of opening 14, from the imaginary center axis 16 of the combustion chamber 5. In a practically tested variant, the diameter D of the nozzle opening of the air nozzles 15 is roughly 1/50th the length 1 of combustion chamber 5 measured along center axis 16. The diameter of the combustion chamber is about half its length. The figures are not to scale.

[0032] A guide tube 17 can be arranged in internal space 9 concentric to the center axis 16. The guide tube 17 is shorter than the length of internal space 9. This diameter corresponds to roughly the diameter of opening 14. It has a spacing from the end walls 11 and 12 that is somewhat less than its radius. Means of fastening the guide tube 17, for example bars, to wall 8 or end walls 11, 12 are not shown.

[0033] The air nozzles 15, as shown in Figure 3, extend into the internal space 9.. For example, they have a roughly truncated conical contour. They are designed so that they produce a straight air jet that causes an injector effect. A fuel feed device 18 is provided to supply fuel. This is formed, for example, by fuel nozzles 19 that are fed by a central line 21. The fuel nozzles 19 can discharge right in front of an air nozzle 15. One fuel nozzle 19 can then be assigned to each air nozzle 15. It is also possible to assign fuel nozzles 19 to only some of the air nozzles 15. In addition, the fuel nozzles 19 can be arranged between air nozzles 15, as shown in Figure 4 as an alternative. The number of fuel nozzles 19 can match the number of air nozzles 15 or differ from it. The fuel nozzles 19 and the air nozzles 15 have the same outflow direction, i.e., the air and fuel are introduced to the internal space 9 in the same direction.

[0034] The combustion chamber 5 also has a preheating device 22 for startup. In the present embodiment it is formed by a spiral-wound filament that can be heated electrically and is accommodated on the inside of wall 8. As an alternative, a burner, an arc generation device or another controllable heat source can be provided.

[0035] The combustion chamber 5 thus described operates as follows:

[0036] During operation of gas turbine 1 the combustion chamber 5 receives compressed fresh air preheated by compression at its inlet 6. The pressure can be in the range from 10 bar to 20 bar, for example. The air is divided among the individual air nozzles 15 and therefore enters the internal space 9 in the form of jets roughly parallel to the cylindrical wall 8. This is shown by arrows 24, 25. The temperature in the internal space 9 is increased by the spiral-wound filaments 23 so that the introduced fuel is ignited. This is fed via fuel nozzles 19, with the fresh air stream, into the internal space 9 in the direction of arrows 24,

25. The fuel now reacts in this internal space on its way from air nozzles 15 to end wall 12. The annular channel formed between the outside of guide tube 17 and the inside of wall 8 therefore forms a reaction channel 26 that is traversed by the fresh air and fuel in the direction of arrows 27, 28.

[0037] The end of the reaction channel 26 is covered by end wall 12 so that the flow, which is indicated by arrows 29, 31 is reversed. Only a smaller part of the formed reaction products flows via outlet 7 through turbine 5 as hot gas, as shown by arrows 32, 33. The larger part recirculates through guide tube 17 back to end wall 11, therefore establishing a recirculation channel 34. The exhaust flowing back in the recirculation channel 34 is at the combustion chamber outlet temperature, for example 1300°C. The mass flow rate is two to five times the feed flow rate of the air through inlet 6.

[0038] The back-flowing gases are deflected radially on end wall 11 and drawn into reaction channel 26 by the inflowing fresh air with an injector effect. The hot exhaust mixes with the inflowing fresh air. The mixing temperature lies above the ignition temperature of the supplied fuel, for example above 720°C. The fuel fed with the fresh air therefore oxidizes completely, roughly along the length of guide tube 17 within the reaction channel 26, without forming flame phenomena. No local temperature peaks develop within the gas volume.

[0039] After heating of combustion chamber 8 and assumption of the described stable flameless operation, the preheating device 22 can be switched off. The flameless oxidation can be maintained in full and partial load operation as long as it is ensured that the combustion chamber 8 is kept overall at a temperature above the ignition temperature of the fuel, and as long as the flow pattern shown is maintained. The guide tube 17 here forms the areal turbulence center of the forming large-volume recirculation stream that has a tire-like or toroidal shape. The turbulence center is therefore localized stably and is coaxial to the center axis 14.

[0040] In an alternative embodiment of combustion chamber 5 shown in Figure 5, the circulation flow is achieved merely by arranging the air nozzles 15 on the rim apparent from Figure 4, formation and arrangement of openings 14, and optionally by shaping of wall 8. The recirculation channel 34 and reaction channel 26 here are not separated from each other by fixtures, but are determined by the forming flow. The turbulence center of the recirculation flow is indicated with a dashed line in Figure 5 at 35. It lies concentric to the center axis 16.

[0041] In a further developed embodiment, a high temperature catalyst is arranged in outlet 7. This serves for reaction acceleration, especially in the lower temperature ranges.

[0042] A modified combustion chamber 5 is shown in Figures 7 and 8. This is designed as an annular combustion chamber. Where reference numbers used thus far are employed,

the previous description applies accordingly. The following explanations serve as a supplement.

[0043] The combustion chamber 5 is an annular internal space 9 arranged concentric to the longitudinal center axis 16 and enclosed by wall 8 both toward the center axis 16 and also outward. As shown in Figure 8, this can transition into the end walls 11, 12 with a curvature that is favorable from the standpoint of flow. Air nozzles 15 that lie on a circle concentric to center axis 16 are arranged in the end wall 11 (Figure 7). The flow direction established by air nozzles 15 is essentially parallel to center axis 16. End wall 12 can be provided with an annular slit-opening 14 or instead with a series of individual openings 14 arranged on a rim. The outer rim, i.e., the limitation 36 lying farthest outward radially, is arranged far enough inward radially that the air jet emerging from air nozzle 15 strikes end wall 12 radially farther out. In other words, as in the previous embodiments, the imaginary linear extension 37 of air nozzle 15 intersects end wall 12 outboard of opening 14. Accordingly, the flow emerging from air nozzle 15 is diverted by 180° before outlet 7 and for the most part flows back to the end wall 11, where it is diverted again by 180°. A large circulating flow is formed that runs along the entire length of the wall 8 of combustion chamber 5. The turbulence center 35 is arranged concentric to the center axis 16. It passes through internal space 9 roughly in the center. As shown with the dashed line, it can be established by a guide device 17' or merely by the shape of wall 8. As in the previous embodiments, flameless oxidation occurs, with a complete reaction between the fuel and the supplied fresh air, on the way from the air nozzle to the end wall 12, so that only waste gases are recirculated.

[0044] Another embodiment of the combustion chamber 5 according to the invention is apparent from Figures 9 and 10. The comments made relative to the combustion chambers according to Figures 3 to 5 apply accordingly. The following applies in addition:

[0045] The combustion chamber 5 according to Figure 9 operates with reverse flow. Whereas in the preceding combustion chambers, the inlet 6 and the inlet [sic; outlet] 7 are arranged on opposite ends 11, 12 of combustion chamber 5, the inlet 6 and outlet 7 in combustion chamber 5 according to Figure 9 are arranged on the same end 11 of combustion chamber 5. This design is suitable for turbines of smaller power. It is typically applicable to turbines with radial compressors. The air nozzles 15 are arranged on a circle that encloses the opening 14 provided in end wall 11. The air nozzles 15 and the opening 14 are arranged concentric to center axis 16. The circulating flow that forms (arrows in Figure 9) again has an annular circulation center 35 positioned concentric to center axis 16. The circulation flow has a mass flow rate that exceeds the mass flow rate of the supplied fresh air by a factor of two to five.

[0046] In comparison with the embodiments just described, the advantage of this embodiment of combustion chamber 5 is that almost the entire internal space 9 is utilized as

a reaction space. Both the path from the air nozzle to end wall 12 and the path from the end wall 12 to the outlet 14 can be used for reaction of the fuel. A very compact design is therefore possible.

[0047] If necessary, the center 35 can be fixed or stabilized by a guide tube 17. In addition, the end wall 12, as shown with a dashed line in Figure 9, can be curved as a torus, i.e., designed as a channel running around the center axis 16.

[0048] A combustion chamber 5 for a gas turbine is set up for flameless oxidation of fuels. For this purpose it has an internal space 9 in which a larger recirculation flow is established. This feeds the introduced air to a hot exhaust stream whose flow rate exceeds that of the fresh air stream. The fresh air and the fuel are fed to the combustion chamber in the same direction, roughly parallel to the wall.